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CONSTANT SUCTION IN THORACIC SURGERY: DESCRIPTION OF AN ANÆSTHETIC APPARATUS

BY

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From the Manchester Co-ordinated Thoracic Surgery Service

IT is common ground among surgeons and anæsthetists that thoracic operations present two major problems. These are the maintenance of the cardio-respiratory reserve in the presence of an open pneumothorax or of a decostalised chest wall, and the prevention of dissemination of septic material or blood to healthy portions of the lungs. It is not our purpose to discuss these problems at length. They have received a good deal of attention and have been tackled in various clinics by different methods and devices. We desire to describe an anæsthetic machine which has been designed and made by one of us (K.B.P.) and which has certain advantages in the field of chest surgery. We shall also offer one or two comments on the working of the machine in practice.

METHODS OF ANÆSTHESIA

The apparatus has been designed specially to make available positive ventilation and continuous aspiration, but the

following list shows the methods of anæsthesia which are possible:

(*a*) Ordinary inhalation anæsthesia with facepiece.
(*b*) Constant or intermittent positive pressure anæsthesia.
(*c*) "Controlled respiration" with pump ventilation.
(*d*) "Secondary circulation" of the anæsthetic gases —reference will be made to this later.

Constant suction can be added to any of these methods. All the customary anæsthetics have been used singly or in combination.

The Anæsthetic Machine

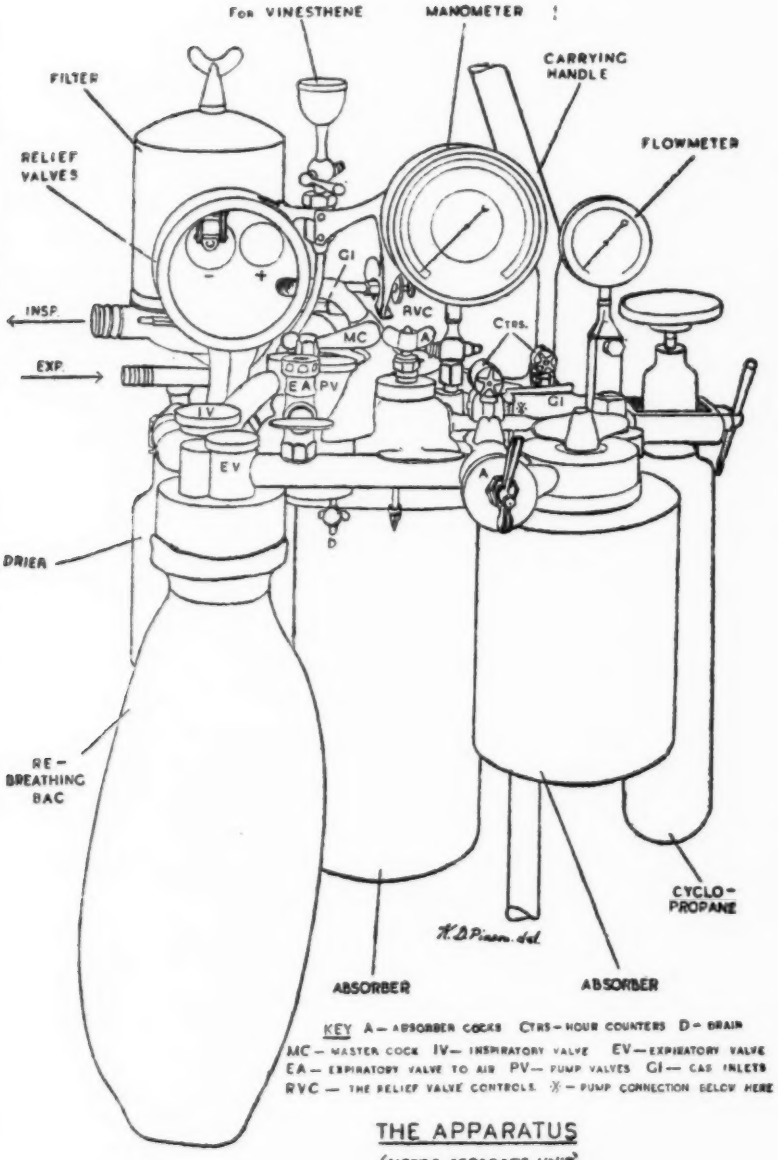
Reference to the diagram and illustrations will help the reader to understand the description which follows.

The apparatus consists of two parts: an upper separate absorption unit with the valves, absorbers, etc., and a lower part or table incorporating the breathing and suction pumps and driving gear. Although the apparatus may appear complicated, it has been found to be simple in use in many sorts of cases, whether the pumps were in action or not.

The machine is of the closed type, the anæsthetic vapours being retained and rebreathed. It has three circuits:

(*a*) The breathing pump circuit.
(*b*) The shortened breathing circuit which cuts out the breathing pump. A master cock (M.C. in the illustration) cuts out certain passages and valves and thus selects circuit (*a*) or (*b*).
(*c*) The suction pump circuit which may be used with either of the other two.

(*a*) *Breathing Pump Circuit.* In the upper unit are two CO_2 *absorbers* which can be used independently and offer little resistance to expiration—an important point. In the larger absorber the soda-lime rests on shelves, over which the expired gases pass. (This arrangement was experimental and is now thought to be unnecessary.) In the case of the second CO_2 absorber the expired gases go through the soda-lime in the usual fashion. Unidirectional flow of the



KEY A — ABSORBER COCKS CTRS — HOUR COUNTERS D — DRAIN
MC — MASTER COCK IV — INSPIRATORY VALVE EV — EXPIRATORY VALVE
EA — EXPIRATORY VALVE TO AIR PV — PUMP VALVES GI — GAS INLETS
RVC — THE RELIEF VALVE CONTROLS. ✳ — PUMP CONNECTION BELOW HERE

THE APPARATUS

(UPPER SEPARATE UNIT)

DIAGRAM OF PULMONARY PUMP APPARATUS.

Cocks are shown in position for pumping circuit, except that both absorbers are "on." The three decks—bottom, middle and top—of the master cock are separated out for clarity: for the shortened circuit they are turned through a right angle. The flow of gases is indicated by arrows—the dotted ones being for the flow past the relief valves.

gases was chosen because it leaves inspiration unimpeded. The *breathing bag* is wide-mouthed and reversible so that it can be easily cleaned. The *hour-counters* are set after every operation to record the length of time the soda-lime has been use. A Schaffer diaphragm *manometer* is illustrated. Perhaps a water manometer, connected to the apparatus as near to the patient as possible, would give even more instructive readings during the phases of respiration than the one which is actually fitted. When the breathing pump is in action the *relief valves* control separately the inspiratory pressures and therefore volumes.

The *Breathing pump* is reciprocating and belt driven by a 1/3 H.P. motor. There are eight speeds, from 19 to 36 strokes a minute, and a variable stroke, so arranged that the piston comes to the top of the cylinder at all adjustments. Thus the full volume of gases determined upon is delivered. No harm results if a greater volume is delivered than that which the patient inspires, as the excess escapes by the relief valves into the bag. These valves which are visible behind glass make it possible accurately to control the force with which the patient is positively ventilated. Indeed he may be completely by-passed so that the gases go into the bag, past the open valves. On the other hand, the valves may be so adjusted that the lungs are expanded with each upstroke of the piston. The patient is able to breathe a larger or smaller amount than that delivered by any given stroke of the pump, or he may breathe out of time with the pump, without causing harm.

(*b*) When the pump is not in use the *Shortened breathing circuit* is selected as it has less resistance. For suction the connection marked 'F' in the diagram is connected to 'E.'

(*c*) *Suction Circuit.* The *Suction pump* is driven by the motor which actuates the breathing pump and, like this, is belt driven and reciprocating. It extracts pus from the trachea and/or pharynx through a *catheter* or *catheters.* We have always used a Magill endotracheal tube, with a special catheter. With the same provision, a face-piece could be substituted for the endotracheal tube. Of the two twin connections of the suction catheter to the rest of the suction

circuit, only one of each (marked 'S' and 'W') is shown in the diagram. The junction of the catheter to the cocks 'S' and 'W' is made by means of a Y-tube. The suction cock 'S' is connected to a series of *four bottles*. The first is a trap for aspirated secretions. The second bottle contains silica gel for the absorption of moisture. The third contains soda-lime and is for the purpose of absorbing the CO_2 which necessarily escapes the absorber system on the breathing circuit, and the fourth is a dust filter. From here the gases pass to the suction pump which blows them back into circulation. If the Y-tube becomes clouded by pus, further observation of aspirated material is hampered. An occasional turn of the cock 'W' permits water from a *fifth bottle* to flush out the Y-tube and restore its transparency.

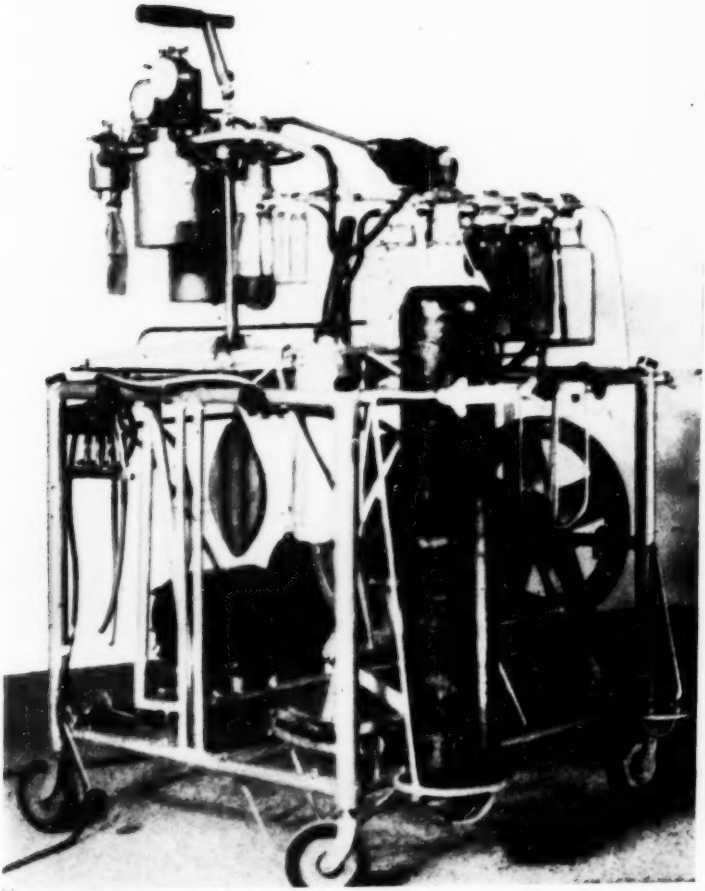
When suction cock 'S' is fully opened a considerable quantity of gas is taken from the patient and the suction circuit takes a corresponding share in the expiratory phase of respiration. The breathing pump is insulated from the exhaust gusts of the suction pump by means of a *buffer bag*.

The inset diagram of the "secondary circulation" breathing bag is self-explanatory. This system, as will be explained later, relieves the patient of all impedance to respiration. The *stethoscope* is necessary to enable the breathing to be observed, because movements of the bag are almost due entirely to the action of the pump.

Discussion

Cardio-respiratory Reserve and Stabilisation of the Mediastinum. There has been a good deal of support for the practice of assisting natural respiration during thoracic operations, either by manual bag pressure (Nosworthy[1]) or by means of a pump (Crafoord[2]), the respiratory centre being lulled to sleep ("controlled respiration"). It should be added that not all anæsthetists agree that controlled respiration is necessary or even desirable (Beecher[3]).

Respiration may be assisted in another way without throwing the respiratory centre out of action. The patient breathes freely in and out of a bag near his face, while a "secondary circulation" to and from the bag is maintained



K.B.P. & A.G.B.

by the pump. In this way the gaseous mixture is kept decarbonised by passage through the soda-lime, and the patient is relieved of all effort which an absorption apparatus ordinarily entails. The whole circuit is completely enclosed and constant suction may be maintained.

The exact place which these forms of assisted respiration will assume in the management of chest operations has not yet been fully worked out. Our own present impression is that for the purpose of preventing excessive mediastinal swing, and in suitable cases, they are superior to the continuous or intermittent positive pressure technique. Even when used only at the end of an operation for the purpose of expanding the remaining unresected lung, positive pressure has in our hands frequently caused some deterioration in the patient's condition.

Prevention of Dissemination of Infective Material. The methods in use resolve themselves into :

(*a*) Suction.

(*b*) Pre- and post-operative bronchial aspiration..

(*c*) Packing of the bronchi.

(*d*) Posture on the table. (Alexander,[4] Blades and Graham[5]).

Most authors insist on the value of periodic removal of secretions from the air passages during the course of thoracic operations. So far as we are aware continuous suction has not hitherto been utilised. It is one of the claims that are made for the machine here described that it provides continuously available tracheal suction without waste of the anæsthetic agents, the whole apparatus being a closed circuit.

Pre-operative bronchial aspiration and packing, however skilfully performed, do take something out of the patient, and are time consuming. This has also been the experience of Halton.[6] It is just the patients in whom these procedures are most called for who may be seriously upset by them at the outset of an exacting operation; and even the most thoroughgoing bronchoscopy does not completely empty the tracheal-bronchial tree of pus. We are convinced that at

any rate a considerable number of patients may be spared the ordeal of pre-operative bronchoscopy through the medium of continuous aspiration.

Crafoord[7] has recommended hyperventilation of the lungs as a means of maintaining a high nitrous-oxide percentage in the gas mixture. We used hyperventilation in a case of lobectomy for bronchiectasis. The immediate post-operative course was entirely satisfactory but, two days later, signs of pulmonary infection appeared and the patient died. At the post-mortem multiple foci of suppurative bronchopneumonia were found throughout all the remaining lobes on both sides. This experience has made us cautious about the force and amplitude of ventilation, and has also dictated gentle and slow expansion of lung tissue when this has been affected at the end of an operation by the method of raising the positive pressure.

Conclusions

(*a*) Relief of respiratory effort (including stabilisation of the mediastinum) by controlled respiration or by "secondary circulation" is of definite value in "dry" cases and old patients.

(*b*) No form of ventilation will overcome the depressing effects of operative trauma, whether due to hilar reflexes, separation of dense adhesions or hæmorrhage. Mechanical methods cannot be expected to do more than sustain the cardio-respiratory reserve in the presence of an open pneumothorax or a decostalised chest wall.

(*c*) Continuous suction (or continuously available suction) is of undoubted value and can replace pre-operative packing and pre- and post-operative aspiration through a bronchoscope in a number of cases.

(*d*) In "wet" cases care is necessary in the employment of any form of pumping, whether mechanical or manual, in order to avoid the dissemination of septic material. The same caution applies to re-expansion of collapsed lung by continuous positive pressure. The risk of dissemination is diminished by the employment of continuous suction.

(*e*) Positive ventilation (pump or manual) is essential if both pleural cavities are opened.

(*f*) The advantage of having positive ventilation immediately available as a resuscitative measure needs no comment.

Our thanks are due to Mr. K. D. Pinson for the line drawing.

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THE DIPLOMA IN ANÆSTHETICS

The following candidates were successful in the last examination for the D.A.:—

D. M. Armstrong, W. B. Bacon, B. N. P. Bannatyne, D. R. Blunn, Mary L. Brown, H. A. Buck, T. A. R. Callender, T. D. Culbert, H. V. Edwards, R. Foregger, D. L. V. Fraser, C. E. D. H. Goodheart, A. J. Gray, A. T. Hawthorne, R. Herschkowitz, A. S. Kenney, E. Kern, M. Kuttner, R. Lee-Michell, J. T. Linklater, Christine M. Millar, F. R. P. O'Hara-Proud, D. I. Rees, Laura M. Rhodes-Clooney, B. W. T. Ritchie, Edith Roth, J. V. Shemilt, M. P. Sherwood, S. Singh, J. A. Smith, F. J. R. Stoneham, J. W. Warrick, W. R. Watson, W.D. Wylie.

AN ANALYSIS OF THE PULMONARY COMPLICATIONS OCCURRING AFTER 579 CONSECUTIVE OPERATIONS

BY

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THE published records of pulmonary complications accruing after operations show a certain degree of agreement as to which types of operation and patient are most likely to produce these complications, but differ widely as to the frequency with which complications occur.

Sutliff and Steele,[1] in an elaborate study of 16 cases of upper abdominal operations, found post-operative complications in almost every case. On the other hand Moir, Ethel and Lamb[2] claim 11,597 anæsthetics were administered with only 93 cases of post-operative pulmonary complications. Figures based on the study of case notes (as opposed to the study of the cases themselves) tend to show a small percentage of complications. Other reasons for the variability of the figures relating to post-operative pulmonary complications are that some report only the major complications while others omit those cases which showed signs of pre-operative respiratory infections.

It appears that the number of pulmonary complications found after operation depends largely on the intensity with which the search for them is carried out. In this series all cases were seen daily by one of us, and all complicated cases by both.

We have included as complicated cases all those with

physical signs of abnormality in the larynx trachea, lungs and pleuræ. We have also included cases of cough unaccompanied by physical signs if there was also sputum or if the cough was persistent for more than two or three days, or if there was at the same time a rise of temperature. No case operated on during the time of the investigation was excluded from the report. Records were kept by us at a small E.M.S. hospital of all cases operated on during a complete year.

The total number of operations was 579. There were no deaths from any cause. The percentage of post-operative pulmonary complications over the whole series was 4.6. The complications encountered were as follows: Cough, 2; bronchitis, 15; atelectasis, 4; bronchopneumonia, 2; pleural effusion, 1; activation of T.B. focus, 1; pulmonary embolus, 1. Bronchitis was the commonest complication and usually began within 48 hours of operation, the patient feeling as though he had caught a cold. These cases expectorated purulent or muco-purulent sputum. They were treated with sulphapyridine and all responded well. It is possible that X-ray examination of some of these cases would have shown that the primary lesion was atelectasis.

The patients with frank atelectasis all complained of pain or discomfort on inspiration within 48 hours of operation. One case was treated by bronchoscopic suction. The other three subsided with breathing exercises and expectorant mixtures. In no case was there a complete collapse of a lung. Both cases of bronchopneumonia were thought to be associated with areas of collapse. They began with diffuse bronchitis on the second day and signs of scattered patches of unilateral broncho-pneumonia developed in three or four days. They responded well to treatment with sulphapyridine.

Intraperitoneal Operations

Table I shows an analysis of the intraperitoneal operations. Operations for hernia show a high rate of complication (33 per cent). Several methods of anæsthesia were used but the majority were given morphine and atropine followed by N_2O and O_2; about half the cases had evipan, or small amounts of ether as supplementary agents. No difference was noted in the resulting complications.

Although the numbers are small, it is interesting to note that 11 pulmonary complications were found after 34 operations for the repair of herniæ, and no complications were found after 20 operations for appendicitis.

TABLE I.

INTRAPERITONEAL OPERATIONS.

Type of operation	Number of operations	Complications	Percentage
Hernia	35	8 Bronchitis 1 Pneumonia 1 Atelectasis 1 Cough	33
Caesarean section	1	0	0
Appendicactomy	20	0	0
Carcinoma of colon	3	1 Bronchitis 1 Pneumonia 1 Atelectasis	100
TOTAL	59	14	23·7

At the meeting of the Royal Society of Medicine, held on November 4th, 1942, recurrence rates after operation for inguinal hernia varying from 12 per cent to 20 per cent were quoted by various speakers.

There can be no doubt that this high rate is partly due to the frequency with which coughing occurs during the first few days after operation (four). Experience shows that this cannot be avoided by using any particular anæsthetic agent or merely by the avoidance of ether. There are three reasons for this. The first is that a large proportion of all patients who suffer from an inguinal hernia do so because they have a chronic cough in addition to a congenital hernial sac. (Half the patients in this series said that they had frequent coughs and several others who denied that they had coughs were noticed to cough in the ward before operation.)

The second reason is that coughing after a hernia operation

is painful and inefficient and mucus may accumulate in the bronchi and afford an opportunity for infection to become established; and the third reason is that after the operation patients are reluctant to use their diaphragms in breathing.

Of the remaining 24 abdominal operations all three post-operative complications occurred in one young soldier who had three operations for a carcinoma of the descending colon. At the time of his first operation (cæcostomy) he was extremely ill and had not recovered completely from an attack of acute bronchitis; after his second operation (under light percaine spinal analgesia up to D4 with supplementary N_2O and O_2 anæsthesia) he had atelectasis; and after his last operation, which lasted two hours (with N_2O and O_2 and ether), he had bronchopneumonia which responded to treatment with MOB693.

During his whole stay in hospital this man's lungs never became quite normal.

Extraperitoneal Operations

As would be expected, Table II shows that the post-operative incidence of pulmonary complications is less than

Table II.

Extraperitoneal Operations.

Type of operation	Number of operations	Complications	Percentage
Ear, nose, throat	400	4 Bronchitis 2 Atelectasis 1 Tuberculosis 1 Cough	2
Hydrocele Varicose veins Haemorrhoids, etc.	120	1 Pulmonary embolus 1 Pleural effusion 2 Bronchitis	3·3
Total	520	12	2.3

in the intraperitoneal cases, 2.3 per cent as compared with 23.7 per cent. Moreover, the type of complication is less severe. No case of pneumonia followed an extraperitoneal operation, whereas two cases of pneumonia followed a relatively small number of intraperitoneal operations.

Ear, Nose and Throat Operations

These patients were almost all soldiers. The majority of the operations were for the removal of tonsils by dissection, or for the removal of part of the nasal septum. There were also a few mastoid operations and operations on the maxillary antra and nasal polypi. In some cases with deflected nasal septa it was found possible to intubate by the nose for the dissection of the tonsils and to pull the tube out of the nose into the mouth for the operation on the nose. The surgeon was satisfied that no damage was done to the nose. These cases are reported as nasal intubations. Nasal intubation was not attempted in the presence of nasal polypi.

Laryngitis was not found post-operatively in any case. A. R. Dingley,[3] has found that occasionally virulent sinus infection has followed nasal intubation for tonsillectomy. This complication was absent in our series.

Table III shows that no case of pneumonia was found after 400 operations in which laryngeal intubation was performed and that nasal intubation compared favourably with oral intubation.[16, 17, 18]

The few complications which we met in the ear, nose and throat cases were all slight except in the case of a patient whose quiescent pulmonary tuberculosis was missed at the pre-operative examination of his chest. This man had a severe nasal haemorrhage some hours after his operation for removal of bilateral nasal polypi and intranasal antrostomy. This necessitated a second anæsthetic when the patient was *in extremis*, and blood was inhaled during the induction. The patient survived, and some weeks later was transferred to a sanatorium with active tuberculosis of both lungs.

TABLE III.
COMPLICATIONS OF 400 INTUBATED E.N.T. CASES.

	Nasal intubation	Oral intubation	Total
No. of cases	233	167	400
Exacerbation of tuberculosis		1	1
Atelectasis	1	1	2
Bronchitis	3	1	4
Cough	0	1	1
Total	4	4	8
Percentage	1.7	2.5	2.0

DISCUSSION

Hypo-ventilation.[1, 5, 6, 7, 8]

All observers agree that lung complications are ten to twenty times more likely to follow intraperitoneal operations. So great is this factor that it tends to overshadow all others. For instance in a graph showing the percentage of complications occurring in each month of the year in a series of mixed abdominal and extraperitoneal cases, it is found that the curve is much more influenced by the percentage of abdominal cases operated on in each month than by the season of the year.

After abdominal operations, especially those involving the upper abdomen, a state of hypo-ventilation ensues which lasts for some days. During this time the diaphragmatic excursion is limited to about one-third of the normal, and its mean position is one which it normally occupies during expiration. There is a similar limitation of movement of the chest wall which is also held in an expiratory position.

Clinical observation of these cases shows that this state of hypo-ventilation can be overcome to a certain extent by breathing exercises for short periods by co-operative patients,

especially if they have been practised in chest and diaphragm expansion before operation. It can also be seen that much better results are obtained if the patients' efforts are assisted by the simultaneous use of CO_2, either by administration or by the use of a partial rebreathing device (such as a rubber face-piece coupled to four feet of wide-bore corrugated tubing. This common observation suggests that CO_2 provides a more effective stimulus to the respiratory centre than the patient is able to provide by his own volition. Clinically this state of hypo-ventilation is a reflex rigidity of the respiratory muscles which resembles that rigidity of the abdominal muscles which is commonly seen in general peritonitis. Hypo-ventilation after operation is a predisposing cause of atelectasis. During thoracotomy areas of lung are seen to contract down and resist the intake of air, but there is not enough evidence to decide whether the intrinsic smooth muscle of the lung partakes in the reflex spasm of hypo-ventilation. That it is not the main factor in many cases is shown from the fact that when there is a definite collapse of a large portion of a lung, the removal of a plug of mucus by coughing or by back-slapping, or by bronchoscope, will immediately cure the condition if it is not of long standing.

The physical condition of the patients[1, 9, 10, 11] has an important bearing on their ability to resist post-operative complication of all kinds, and published statistics invariably show where the patients have been graded according to their pre-operative condition that the better their condition before operation the better their chances are of avoiding post-operative pulmonary complication, and vice versa. It has also been shown that the presence of infective organisms in the respiratory tract before operation has an unfavourable influence on the incidence of post-operative lung complications.

The severity of the operation[1, 10, 11] or the amount of trauma inflicted by the surgeon undoubtedly has an influence on the post-operative progress of the patient.

The length of the operation[1, 10, 11] appears statistically to influence the likelihood of post-operative lung complications; this may be fallacious, because the longer operative procedures are usually the most traumatic, e.g. abdomino-

perineal resection of the rectum and partial gastrectomy. We confess that we have noticed that a slightly imperfect airway continued over an hour or so—especially in babies—is a predisposing cause of post-operative depression and complications.

Sex is a factor in that men are nearly twice as liable to lung complications as women. Morton[12] has produced figures which show that this is probably due to a much higher incidence of heavy smokers among the men.

The season of the year is commonly held by surgeons to be important, but most published figures do not bear this out. It is possible that it is true of certain types of operation, such as nose and throat operations and not of others.

Anæsthetic agents[10, 13, 14, 15] are often blamed for producing respiratory complications, but the statistics are conflicting, and it is probable that the judgment and skill of the anæsthetist are more important than the agent he uses.

Dawkins has pointed out, however, that heavy premedication, with its usual accompaniment of prolonged respiratory depression, results in a greater frequency of post-operative lung complications. Most anæsthetists would agree that on the whole the sooner the patient recovers his cough reflex and takes charge of his own airway the better.

Summary

A careful survey has been made of the pulmonary complications occurring after 579 consecutive operations which were performed in a small E.M.S. hospital in one year.

The incidence of complications for the whole series was 4.6 per cent. There were no deaths from any cause. The incidence for hernia operations was 33 per cent. Intubated cases showed an incidence of 2 per cent. The complications following nasal intubation were slightly less than those following oral intubation.[16, 17]

The most serious complication followed an operation on a patient in whom pre-operative examination of the chest failed to reveal the presence of quiescent tuberculosis of the lungs.

The relative importance of some causative factors of post-operative lung complications is discussed.

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EXPERIENCES WITH 500 TRICHLORETHYLENE (TRILENE) ANÆSTHETICS AT AN E.M.S. HOSPITAL

BY

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TRILENE has been used as the anæsthetic in an E.M.S. hospital, most of the patients being young men in the Services. The youngest of them was aged 18 years and the oldest 53 years. The commonest age groups were between 20 and 35 years. Toxic subjects and those suffering from cardiac abnormalities were not anæsthetised with Trilene.

Three cases were complicated by profound shock and included in the series. Operation was undertaken for most orthopædic lesions including major procedures and general surgical conditions, excluding intra-abdominal and intrathoracic lesions.

PREMEDICATION

The most satisfactory premedication in order to get the best muscular relaxation was as follows:

Nembutal gr. 1½, the night before operation; morphia gr. 1/6, atropine gr. 1/100, and nembutal gr. 1½ to gr. 3, all given 1½ hours before operation. Omnopon gr. 1/3 and scopolomine gr. 1/150, morphia gr. 1/4, and atropine gr. 1/100, were also tried but muscular relaxation was frequently unsatisfactory and the lithotomy position difficult to maintain. Trilene was also given without premedication but relaxation was poor, tachypnœa often troublesome and it was useful only to reinforce nitrous oxide-oxygen anæsthesia in very minor surgical procedures. The conflicting reports of the action of Trilene anæsthesia may be due in part to different methods of premedication.

Induction and Maintenance of Anæsthesia

The apparatus used in each case was the standard Boyle machine using partial re-breathing. Anæsthesia was first induced with a few breaths of nitrous oxide, the flowmeter being set at 8 to 10 litres per minute. Trilene was then gradually turned on, and after a few more breaths nitrous oxide was turned on to 2 to 4 litres per minute, and oxygen to 1 to 2 litres per minute. The gases were blown over the Trilene so that the surface of the liquid was just ruffled. The machine was kept set in this manner until the third stage of anæsthesia had been reached, which usually took 4 to 5 minutes. (cf. Langton Hewer.[1]) The mask was strapped tightly on to the face in order to give an air tight junction as far as possible. Induction was smooth, quick and pleasant; there was no salivation, only occasionally a little struggling, but sometimes there was raising and a little stiffening of one or more limbs. This phenomenon, in my experience, is more common in Trilene than in ether anæsthesia. Violent struggling was absent if adequate premedication had been given, even in the most robust subjects. The patient's colour was good throughout the anæsthetic. The maximum depth of anæsthesia was attained within ten minutes and it was no use trying to deepen the anæsthesia after this time (cf. Haworth and Duff[2]). The patients were maintained in the third stage of anæsthesia, planes 1 or 2, often with the Trilene considerably turned down.

The Effect of Trilene on the Respiratory and Cardio-vascular Systems

Respiration. Respirations were usually 30 to 40 per minute, excepting in unpremedicated patients when tachypnœa was often present, sometimes up to 60 or over. Langton Hewer[2] reports that tachypnœa was not troublesome when air was used. There were four cases of respiratory arrest and each occurred in the same manner. The patients were all in stage 3, planes 1 or 2, with respirations regular and of good volume when breathing suddenly ceased. However, a little artificial respiration started automatic breathing and the rest of the anæsthetic was uneventful except in two cases.

One had a respiratory arrest which was quickly overcome in the manner described, but after about 10 minutes a second arrest occurred and 3 to 4 minutes of artificial respiration were necessary to restart automatic breathing. The other case will be described later. Each respiratory arrest occurred after the anæsthetic had been given for 15 to 20 minutes.

Cardio-vascular System. The systolic blood-pressure was occasionally increased from 10 to 30 mm. Hg. and a small rise in pulse pressure was sometimes found. The surgeons never complained of excessive hæmorrhage. The effect of Trilene on the pulse was interesting, about 80 per cent of the patients showing some change after anæsthesia had been in progress for more than ten minutes. Slowing was about twice as common as an increase in rate; 16 per cent of the cases showed irregularities though none of these occurred in the first ten minutes. Gordon and Shackleton[4] report 19 per cent irregularities using the closed circuit. Some patients did not show cardiac irregularities until an hour or more after the beginning of anæsthesia. None of the irregularities were allowed to persist for long. A change over was made to ether in the Boyle machine or to open ether if the operation was not nearing completion. The pulse became normal in from 3 to 10 minutes in every case after the change to ether. Some cardiac irregularities were watched after the cessation of anæsthesia and in every instance the pulse became regular in 3 to 10 minutes after the patient began breathing air. Only a few cases in the series were intubated and they showed no cardiac irregularities. Philip Ayre[5] notes that he had very few cardiac irregularities in his series. However, he always used his open T-piece intratracheal anæsthesia, thus admitting air. The air drawn in through the T-piece dilutes the Trilene vapour reaching the lungs and may account for his very low percentage of cardiac irregularities.

Adrenaline has a very deleterious effect on the pulse in Trilene anæsthesia. Lloyd Williams and Hewspear[6] report ventricular fibrillation and Gordon and Shackleton[4] a weak, rapid and thready pulse. Langton Hewer[1] reports less capillary oozing in Trilene than in ether anæsthesia. In view of these findings is it possible that certain concentrations of Trilene in the blood have a stimulating effect on the adrenal

glands, thus releasing abnormal quantities of adrenaline into the blood stream? Unfortunately it has not been possible to carry out further investigations on this point.

Relation to Muscular Relaxation and Recovery

Relaxation of the skeletal muscles was found to be good when nembutal had been given. The carrying out of orthopædic manipulations including manipulations of the spine was particularly satisfactory. Anæsthesia was rapid and the patients had always regained consciousness before leaving the theatre. Many other short cases came round in the theatre and the recovery time of the remainder was usually shorter than with ether. A few of the operations lasted one to one and a half hours but none had a delayed recovery. Many subjects did not miss a meal after anæsthesia which fact was noticed by other patients in the ward, many of whom asked to be given the ' new anæsthetic ' when it was their turn.

Effects on Complicated Cases

A few patients suffering from coryza were anæsthetised for short operations and one or two remarked that the anæthetic had cured their colds and none was made worse.

Three patients suffering from profound shock were anæsthetised with Trilene and in two of them the pulse and blood-pressure were unrecordable before operation. The duration of operation was 20 to 30 minutes and in each case the pulse and blood-pressure became recordable during anæsthesia. The condition of all these patients appeared to be considerably improved at the end of operation though it must be noted that prior to starting anæsthesia two patients had been put on intravenous plasma.

Patients suffering from chronic bronchitis were included in the series and no exacerbation was noted after operation.

Cardiac cases were excluded on account of the chemical similarity of Trilene to chloroform.

Complications Attributable to Trilene Anæsthesia

(1) Chest complications were present but were less frequent and of a less severe character than with ether. They were

usually cases of mild tracheitis or bronchitis which cleared up in a few days. There were also two cases of collapsed lower lobes, one of them bilateral.

(2) Two patients developed widespread giant urticaria during induction, which took a few days to subside. Another two developed urticaria two days after operation, with recurring attacks for two or three successive days. Having had experience of the condition during Trilene anæsthesia we thought that these two delayed cases were also due to the anæsthetic.

(3) Several patients had generalised sweating during anæsthesia and one complained of sweating for two or three hours after recovery.

(4) Nausea and vomiting were infrequent and then only slight in character. There appeared to be some relation to the duration of anæsthesia and the occurrence of vomiting. Short Trilene administrations never seemed to upset patients.

(5) One patient with rather prominent eyes had a mild conjunctivitis the following day but this cleared up following treatment within 24 hours.

Trilene as an Inducing Agent to Ether

The most surprising findings in the series were in cases where the anæsthetic was changed from nitrous-oxygen-Trilene to nitrous oxide-oxygen-ether. The apparatus used was again the standard Boyle machine with partial re-breathing. Twenty-five patients were anæsthetised with this sequence and nine patients were changed over to ether anæsthesia because the pulse had become irregular. Eight patients had Trilene in induction only, some not more than a dozen breaths and the rest were turned over to ether because the surgeon required more relaxation.

In every case Trilene was turned off before the ether was turned on. Every patient gradually developed a rise in blood-pressure and a rise in pulse pressure of from 5 to 88 mm. within 10 to 20 minutes of the change over. The surgeon often complained of excessive bleeding and five of the 25 patients had hæmorrhages. Three had epistaxis, one of a very violent character; one had hæmorrhage from the gums

and another bled violently from hæmorrhoids upon which the surgeon was operating. All these patients had an oral airway and none was intubated. The hæmorrhages all ceased after the anæsthetic was stopped and the patient allowed to breathe air or was put on to open ether admitting plenty of air.

The cases complicated by hæmorrhages were as follows:

The same premedication had been given in all cases, i.e., morphia, gr. 1/6; atropine, gr. 1/100; and nembutal, gr. 3. The blood investigations were carried out a few days after operation.

Case 1. Male, aged 18 years. Operation: orchidopexy.

Induction was smooth; after about 10 minutes Trilene was turned off and ether was turned on because the pulse had become irregular. The pulse became regular 3 to 4 minutes after the Trilene was turned off. Before operation the pulse was 126 and the blood-pressure 130/95. After about 10 minutes on ether the pulse was 94 and the blood-pressure 160/110. When the mask was removed from the face the patient was having considerable nasal hæmorrhage.

Blood investigations were:

Hæmoglobin, 86 per cent; red cells, 5,450,000 per c.mm.; colour index, 0.8; platelets, 215,200 per c.mm.; prothrombin index, 109. Bleeding time not prolonged. No microscopic abnormalities of red or white cells.

Case 2. Male, aged 41 years. Operation: hernial repair.

A change over to ether was made because the patient had a respiratory arrest and there was violent sweating. Before operation the pulse was 108 and the blood-pressure 130/90. After 10 minutes on ether the pulse was 96 and the blood-pressure 170/100. This patient had considerable nasal hæmorrhage.

Blood investigations were:

Hæmoglobin, 88 per cent; red cells, 5,050,000 per c.mm.; colour index, 0.9; platelets, 227,250 per c.mm.; prothrombin index, 105. Bleeding time not prolonged. No microscopic abnormalities of red or white cells.

Case 3. Male, aged 18 years. Operation: excision of varicose veins.

This patient had Trilene in induction only which was very smooth. After about 20 minutes on ether moist sounds were heard, and on removing the mask the patient was having a violent nasal hæmorrhage.

Before operation the pulse was 96 and the blood-pressure 150/100. At the time of hæmorrhage the pulse was 120 and the blood-pressure 180/110. The operation was finished with open ether and oxygen admitting plenty of air and the hæmorrhage soon ceased after the change over to open ether. Unfortunately it was not possible to carry out blood investigations on this patient.

CASE 4. Male, aged 37 years. Operation: excision of varicose veins.

This patient was put on to ether because of an irregular pulse which soon became regular after the change over. Before operation the pulse was 72 and the blood pressure 130/110. After about 15 minutes on ether the pulse was 84 and the blood-pressure 200/100. This patient had bleeding from the gums which were severely affected by pyorrhœa. The blood-pressure was taken several times immediately after the anæsthetic had been withdrawn and within 7 minutes it gradually went down to 120/90.

Blood investigations were:

Hæmoglobin, 70 per cent; red cells, 6,050,000 per c.mm.; colour index, 0.58; platelets, 245,000 per c.mm.; prothrombin index, 100. Bleeding time not prolonged. No microscopic abnormalities of white cells but red cells rather hypochromic.

CASE 5. Male, aged 19 years. Operation: hæmorrhoidectomy.

A change to ether was made because of an irregular pulse which soon became regular. Before operation the pulse was 72 and the blood-pressure 130/90. After about 10 minutes on ether the blood-pressure was 170/100. The pulse was not recorded. The surgeon found excessive hæmorrhage from the operation site which could not be stopped until the anæsthetic was discontinued.

Blood investigations were:

Hæmoglobin, 88 per cent; red cells, 5,120,000 per c.mm.; white cells, 9,500 per c.mm.; colour index, 0.8; platelets, 204,800 per c.mm.; prothrombin index, 120 per cent of normal.

It will be noted that all these blood investigations lie within normal limits and that the cause of the hæmorrhages could not be in any abnormal blood condition.

A control series was then undertaken with a change over from nitrous oxide-oxygen-Trilene to open ether and oxygen, admitting plenty of air. This sequence brought about little alteration in blood-pressure and only one or two patients showed a small rise in pulse pressure, this occurring after a layer of gamgee tissue had been put over the mask, thus

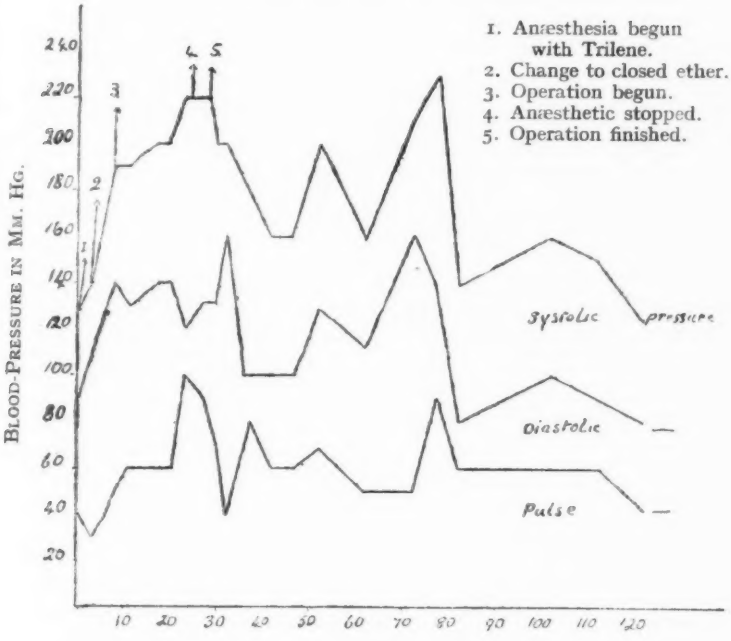
partially excluding air. After open ether had been given for about 15 minutes two patients were put on nitrous oxide-oxygen-ether from the Boyle machine and in each case within a short time there was a rise in blood-pressure and pulse-pressure.

Is the cause of this troublesome rise in pulse-pressure occasionally complicated by hæmorrhage lack of some inert non-absorbable gas, e.g. the nitrogen of air which distends the lung alveoli, or is it due to some increased carbon-dioxide content of the blood together with the presence of Trilene and ether?

This series of Trilene-closed ether sequence is small, but in view of the 20 per cent of hæmorrhages it was decided not to use it again. All the cases did very well ultimately but it is possible to imagine more serious hæmorrhages, i.e. from a gastric ulcer, tuberculous lungs, rupture of sclerosed arteries. Trilene has been suggested as an analgesic in midwifery.[3] However, if it be necessary for operative interference requiring full anæsthesia then closed ether might cause very serious hæmorrhage. The rise in pulse-pressure has been so constant that it is quite conceivable that the Trilene-closed ether sequence may be put to some use when operating on patients suffering from profound shock.

It was not possible to make many investigations on the blood-pressure during the recovery period but the accompanying graph shows the pulse-pressure to be very labile for one and a half hours after the end of operation. A field of further investigation as regards the effect of this anæsthetic sequence in relation to shock would seem to be worth while.

An anæsthetist may be described as the surgeon's accompanist. He must know or be able to assess the tempo of his surgeon and thus be able to shade the anæsthesia through the varying phases of an operation with due regard to the condition of the patient and the surgeon's requirements. This interesting temperamental anæsthetic known as 'Trilene' which must have proper premedication, likes fresh air and makes the patient quarrel with closed ether, is only suitable in certain types of operation in some patients. Relaxation is not as complete as in ether anæsthesia. It is, however, sufficient



Blood-pressure in a case of hernial repair. Anæsthesia with nitrous oxide-oxygen-trilene followed by nitrous oxide-oxygen-closed ether.

for operations such as hernial repair and hæmorrhoidectomy. As it is non-explosive, non-irritant to the lungs, does not appear to give serious trouble in the first few minutes and is cheap Trilene is a useful tool in the armamentarium of an anæsthetist and is often the anæsthetic of choice.

Summary

1. Adequate premedication is necessary for good relaxation.

2. Trilene appears to give no serious trouble during the first few minutes and is therefore very suitable for short administrations.

3. A large proportion of patients developed cardiac irregularities after the first 10 minutes when the Boyle machine is used.

4. After a change to ether anæsthesia of 10 minutes' duration or more in the Boyle's machine a rise in blood-pressure and pulse-pressure takes place which may start a hæmorrhage.

5. A change to open ether admitting air does not cause a rise in blood-pressure.

I am grateful to Dr. Freida Young, resident pathologist, for carrying out the blood investigations in this series; also I wish to thank Dr. J. H. Thomas, medical superintendent at Pinderfields E.M.S. Hospital, Wakefield, for permission to publish these cases, and the surgeons for their co-operation.

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TRICHLORETHYLENE (TRILENE) ANÆSTHESIA IN THE PRESENCE OF ELECTRIC CAUTERY

BY

DAVID HEWSPEAR, D.A.

NUMEROUS references have been made to trichlorethylene breaking down under the influence of heat into various toxic products such as chlorine and phosgene,[1, 2, 3] but a search into the literature soon reveals that with the exception of a few investigations done on the Continent our knowledge of the subject is singularly incomplete. Beilstein and others[4, 5] state that between the temperatures 450°C and 700°C. a number of breakdown products occur, but phosgene is not one of them. If, however, ozone be present, auto-oxidation takes place, to give dichloracetylchloride + carbonmonoxide, phosgene and other products.

A recent discussion in the *British Medical Journal* on the use of diathermy in the operation of laryngofissure under Trilene anæsthesia has brought most conflicting and emphatic views on the subject.[6, 7] Clendon,[8] for example, maintains that since phosgene produces lachrymation and coughing in half the toxic dose, this acts as a safeguard; he, however, misses the important point that once the patient is under anæsthetic he is not in a position either to lachrymate or cough; and in any case, phosgene is not the only product of the combustion of trichlorethylene which would produce these signs.

Using an apparatus designed to approximate the conditions under which Trilene is actually administered (Fig. 1), chlorine, hydrochloric acid, chloromethylformates and phosgene were tested for and estimated where possible; the liberation of ozone from oxygen under the effect of electric diathermy was also investigated. It was soon evident that the rate of flow of gases, type of electrode, heat of reaction

and period of contact profoundly altered the yields of by-products; and whilst the estimation of chlorine and hydrochloric acid were comparatively simple, phosgene was to

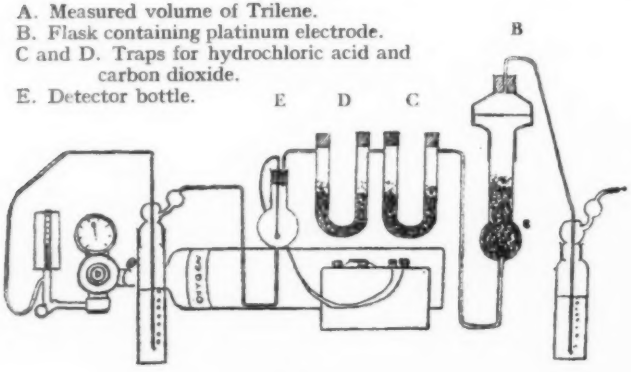

FIG. 1.

offer much greater difficulties, and unless great care in the rate of flow of oxygen was exercised the absorption of chlorine and hydrochloric was incomplete, and entirely fallacious results obtained for the percentage of phosgene. As noted by previous observers, the presence of even small traces of metallic chlorides resulting from the action of chlorine on the apparatus accelerated all the reactions.

APPARATUS

This consisted essentially of a "bubble through" glass cylinder (A), connected to a flask of about 150 c.c. capacity (B), which is approximately equal to the "dead space" of the mouth and trachea containing a platinum cautery such as is used in nasal surgery. A cautery was chosen in preference to diathermy because the greater surface area of heated platinum gives higher yields, and in actual practice a cautery is as liable to be used as diathermy. Oxygen measured off by a Heidbrink flowmeter was used to vapourise the Trilene. (C) consists of 'U' tubes and cylindrical absorber, each containing pumice granules, on to which a mixture of sodium

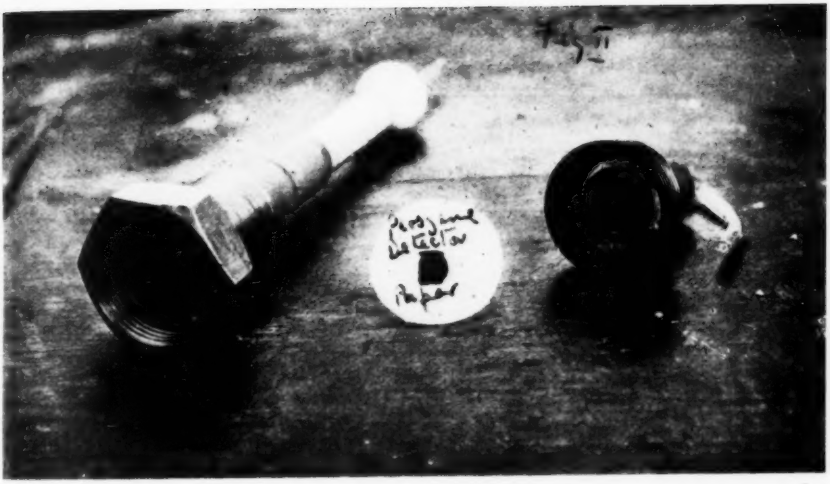

FIG. 2.

thiosulphate and potassium iodide had been absorbed for the removal of chlorine and hydrochloride acid as recommended by the Department of Industrial and Scientific Research. (D) is a standard filter-paper holder for the detection and estimation of phosgene. (E) is a detector bottle for any gases escaping. All connections were of glass, closely fitted together by black rubber and wax corks. Metals and red rubber were avoided owing to their reaction with chlorine.

Methods

(1) *Ozone.* A personal communication from the British Oxygen Company stated that ozone is completely absent from oxygen supplied by them, and this was confirmed by testing with starch/iodide paper, which is sensitive to about 1:1,000,000. A flow of one litre per minute for 30 minutes over intermittently heated platinum failed to reveal any measureable amounts of ozone.

(2) *Chlorine.* In this and in subsequent estimations, flows varying 250 c.c. to 5 litres were maintained for periods up to 30 minutes whilst the cautery was kept at a temperature of 900°C. to 1,000°C., i.e. a cherry-red heat for 5-minute intervals with 5-minute rests between. Experience showed that if the cautery be used for more than five minutes at a time it tended to burn out rapidly. It is doubtful whether any operation would involve the use of diathermy for a longer period than this. Chlorine was proved to be present by a positive reaction with starch/iodide paper and also by the yellow coloration produced with orthotoluidine in hydrochloride acid, and was estimated quantitatively by passing the gases through two wash-bottles containing a solution of 4 per cent potassium iodide and titrating the liberated iodine with N/100 sodium thiosulphate using starch as an indicator.

(3) *Hydrochloric and other acids.* The total acidity was estimated by means of standard caustic soda and phenolphthalein; any chloro-substituted acids being thus also taken into account. Phosgene and chloromethylformates which liberate hydrochloric acid on hydrolysis appear then as acid bodies also. Estimation of chlorides by means of silver

nitrate and potassium chromate did not give a satisfactory end point.

(4) *Chloromethylformates*. This was tested for by adding one drop of 1 per cent phenol and overlaying with conc. sulphuric acid, a red zone at the interface being a positive result.

(5) *Phosgene*. The method finally adopted was that recommended by the department of Industrial and Scientific Research,[1] and by Jacobs,[9, 10] whereby, in the absence of hydrochloric acid and chlorine, a yellow stain proportional in depth to the amount of phosgene present is produced on a No. 1 Whatman filter paper soaked in a mixture of diphenylamine and *p*-dimethylaminobenzaldehyde in carbontetrachloride and dried in carbondioxide (Harrison's Reagent). These must not be exposed to light or kept in stock too long. The method of estimating phosgene by precipitation of diphenylurea from a saturated solution of aniline requires the separation of trichlorethylene vapour first.[9]

It cannot be stressed too strongly that all traces of chlorine and hydrochloric acid must be completely removed, and whilst in the case of chlorine this is comparatively easy the absorption of hydrochloric acid is more difficult; caustic soda must not be used owing to its reaction with phosgene, and wet absorbers cause loss by solution and subsequent hydrolysis. The rate of flow must be so adjusted that no traces of hydrochloric acid or chlorine come over before testing for and estimating phosgene, and even with absorber in addition to those used above this rate had to be below one litre per minute. Furthermore, on testing with pure phosgene a train of absorbers caused some loss of phosgene, probably by retention physically.

Results

It was soon evident that the percentage of chlorine and hydrochloric acid liberated was inversely proportional to the rate of flow of gases—this varied from 0.85 mg. per litre at 250 c.c. per minute to 0.012 mg. at five litres per minute. The limits given by Jacobs[10] for toxic effects are after several hours exposure 0.001 to 0.003 mg. per litre up to 0.1 mg. per litre for exposures up to one hour; so it will be seen that

the amount of chlorine liberated is not likely to give rise to serious effects unless a slow rate of flow is maintained together with the continual use of a cautery or diathermy. The figures actually obtained were:

Rate of flow	Period of flow	Chlorine (average figures)
250 c.c. min.	30 mins.	0.85 mg. per litre
500 ,,	30 ,,	0.70 ,, ,,
1000 ,,	30 ,,	0.47 ,, ,,
2000 ,,	30 ,,	0.38 ,, ,,
3000 ,,	30 ,,	0.22 ,, ,,
4000 ,,	20 ,,	0.12 ,, ,,
5000 ,,	20 ,,	0.10 ,, ,,

Similar results were obtained in the case of hydrochloric and other acid gases, the figures being:

Rate of flow	Period of flow	Acid liberated
500 c.c. min.	30 mins.	4.7 mg. per litre
1000 ,,	20 ,,	2.9 ,, ,,
2500 ,,	20 ,,	1.08 ,, ,,
5000 ,,	20 ,,	0.92 ,, ,,

But since the maximum toxic dose tolerated for 30 to 60 minutes is 1.5 to 3 mg. per litre, the margin of safety is somewhat smaller than that of chlorine.

As previously stated, phosgene offered greater difficulties; the flow had to be maintained at below one litre per minute or interference by unabsorbed chlorine and hydrochloric acid became a serious factor. The efficiency of the phosgene papers and apparatus was checked by pure phosgene in capillary tubing similar to that used for A.R.P. tests. The time taken to reach a standard colour corresponding to 0.41 mg. per litre was noted, and this averaged 30 minutes and 20 minutes respectively for rates of flow of 250 c.c. and 500 c.c. per minute, giving a figure of 0.67 mg. and 0.53 mg. per litre. Though these figures are above the toxic dose, it is fair to assume from the figures for chlorine and chloric that the rate of flow at 5 litres per minute would be 1/5 or

even less than at 500 c.c. and would lie in the region of 0.1 mg. litre. An exposure of 30 to 60 minutes with a cautery continuously in use would, at this concentration, cause toxic effects, but this is much more than is ever likely to be actually used. However, increasing the rate of flow to 7 or 8 litres per minute would soon abolish any possibility of phosgene poisoning.

Chloromethyl Formates. A very doubtfully positive reaction was obtained and was not considered to merit further investigation.

Summary

Under conditions resembling those in which trichlorethylene is actually given in the presence of an electric cautery, the amount of the most important of the toxic products liberated, normally phosgene, chlorine, hydrochloric and other acids, are less than that likely to produce symptoms.

It is recommended that the rate of flow of gases be kept at five litres per minute.

For co-operation in this work my thanks are due to the Medical Research Council, the Department of Industrial and Scientific Research and Dr. Luntz Wills, Pathologist to the Royal Free Hospital.

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DEVELOPMENTS IN SPINAL ANÆSTHESIA*

BY

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PROFESSOR Bier, in Germany, after some experiments, was the first to start spinal anæsthesia, in 1887, after allowing himself to be injected with cocaine. As cocaine, though successful, was found highly toxic, later on many other drugs, e.g., alypin, psicaine, tutocaine, tropacocaine, stovaine, etc. were used, and recently larocaine, spinocaine, duracaine, intracaine, ponotocain, procaine, meticaine, neocaine, planocaine or novocaine and percaine or nupercaine are used. There were many drawbacks to spinal anæsthesia in those early days, e.g. toxicity of the drug used, fall of blood-pressure, uncontrollability of extent and duration of the analgesia, nervous and other sequelæ, and a fairly high mortality rate. All these were mostly due to lack of knowledge about the *modus operandi* of the solution injected. Even to-day, though improvements are made, yet we are not fully able to understand and control it. New theories regarding fall of blood-pressure, posture to be adopted, causes of complications and sequelæ, are being brought out from time to time, as well as new drugs. It is on account of this lack of perfect controllability and safety, and lack of thorough knowledge about the subject and the incidence of untoward symptoms, though very rare, that some surgeons in the world, and an eminent surgeon in Bombay, even now never use spinal anæsthesia. The theories regarding fall of blood-pressure are as follows:

1. Muscular relaxation with diminished respiratory

* A lecture delivered before the All-India Medical Conference, Lahore, 1942.

capacity and negative intrathoracic pressure due to paralysis of abdominal and lower intercostal muscles.

2. Splanchnic dilatation.

3. Paralysis of vaso-constrictors, white rami and the sympathetic chain.

4. Cerebral anæmia, secondary to splanchnic dilatation.

5. Vasomotor paralysis and sudden absorption of the anæsthetic drug.

6. Toxicity of, and individual susceptibility to the drug.

7. Anæsthetisation and dysfunction of the paraganglia, the choromaffin bodies, the suprarenals, and the cortical bodies or accessory suprarenals. It is now believed that when spinal anæsthesia causes an inhibition of the secretions of these glands the result is a systemic suprarenin depletion and a drop in blood-pressure. Therefore it is suggested that to maintain the blood-pressure, even in high spinal anæsthesia, a suprarenin intramuscular reservoir should be created by injecting an adequate amount of suprarenin into the gluteal muscles as may be needed during the spinal anæsthesia.

We shall now very briefly see what new methods, theories and drugs are evolved and their suitability in various conditions. As the main difficulties encountered in spinal anæsthesia were toxicity and short duration, other drugs have been added with the spinal anæsthetic agent, with a view to making it safe and prolonging the duration of an analgesia. Toxicity of the drug due to rapid diffusion in the cerebrospinal fluid sometimes produced poisoning of the medullary centres and paralysis of phrenic nerve roots, and death. Therefore, to prevent this, other drugs which made the spinal anæsthetic solution viscous and not readily diffusible were added, viz., gliadin, gum arabic, amyloprolamine, propantriol, etc. What is known as spinocaine (Pitkin's Heavy Solution) contains these drugs with strychnine in addition to the main drug, novocaine. Spinocaine light solution contains novocaine, gliadin, and alcohol. Strychnine was first added by Jonnesco for stimulation of the respiratory centre, and thereby any high level of anæsthesia was obtainable and any operation on the head could be done. Solutions of too

short duration require supplementary anæsthesia, and those which are prolonged for many hours are also disadvantageous as they keep the patient's condition depressed; therefore, heavy duracaine, pontocaine, etc. are sufficiently long for any average operation of about 1½ hours, and thus avoid both the Scylla of too short, and the Charybdis of too long.

There are three types of solution: hypobaric or light, e.g. tropacocaine, novocaine in aq. destil, or cerebro-spinal fluid, percaine 1-1,500, etc.; hyperbaric, or heavy, e.g. stovaine, either Chauput's or Barker's solution, percaine in 6 per cent in glucose, novocaine in glucose, procaine, etc.; and isobaric, i.e. of the same specific gravity as the cerebro-spinal fluid. Addition of alcohol lightens the specific gravity, whereas dextrose, glucose, and sodium chloride increase it. Even a slight fault in technique may mar the result. As solvents of drugs various things are used, viz., aq. destil, normal saline, serum, cerebro-spinal fluid, Baylis acacia fluid, oils, etc. The dose varies as age, length of spinal column, height of analgesia required, and duration of operation. Besides the ordinary type of spinal anæsthesia, new modifications in technique are: high, low, total, unilateral, segmental, unilateral plus segmental, zone anæsthesia, peridural, balanced, continuous or fractional.

I shall only make a few observations about these methods:

It must be impressed that spinal anæsthesia is unsuitable in both very high blood-pressure and in low blood-pressure cases. Some people believe that if the blood-pressure is high the fall due to spinal would be good, but such is not the case as the kidneys often cease to function.

Ordinary Spinal Anæsthesia can be obtained by injecting (*a*) hypobaric, (*b*) hyperbaric or (*c*) isobaric solution. To get the best results with the first type of solution I have found it advantageous to turn the patient first on one side, then on the other side, and then on his face after the injection for a couple of minutes, and then put on the back in a slight Trendelenberg position, and the height of analgesia is tested. All the nerve roots thus get soaked in the solution, and good motor and sensory anæsthesia is obtainable. If a heavy

solution is used the patient is at once turned on the back, with a slight lowering of the head of the table, keeping the shoulders and head raised on pillow. The skin sensation is tested in all cases, and to check further rise of the level of analgesia the table should be kept flat for a few minutes, but may thereafter be lowered without harm. The isobaric solutions are not so easily displacable up and down as the heavy or light ones, and are sometimes unreliable. If it is remembered that the specific gravity of cerebro-spinal fluid ranges between 1.003 to 1.007, and that it varies in different heights of the spinal column as well as it varies in shock and in extremes of age, it may be easy to understand that the so-called isobaric solution after injection and mixing with the spinal fluid cannot remain as such. It is preferable to inject with the patient in a lateral position than in the sitting posture, for though the latter is easy for getting access to the space, a heavy solution may quickly gravitate down and a light one shoot upward if delay occurs in making the patient lie down, and thus may spoil the result. Whilst puncturing in a child or an infant I prefer to remove the stilette at once after the skin puncture and push only the needle carefully till the fluid appears, so that there is no danger of pushing the needle too far in.

High anæsthesia is obtainable in any of the following ways: Injection at a higher level, using a bigger volume, barbotage (i.e. withdrawing and mixing a little cerebro-spinal fluid with the solution and re-injecting), manipulations of the table and injecting a warm solution. As there is stagnant tissue anoxia, oxygen should be given throughout the operation and later on for some time. As prophylactic for fall of blood-pressure, ephedrine, pitressin, neosynephrin, phedracine are useful. Trendelenburg position counteracts the fall in blood-pressure.

Low or lumbar analgesia is easily obtainable with a small dose of a hyperbaric solution with the patient in a sitting position. If he is too weak to sit up during and a few minutes after the injection, a semi-recumbent position will serve the purpose of gravity. Ano-rectal, perineal, scrotal and penile operations could be done by this method, which gives a

saddle-shaped area of anæsthesia only affecting the sacral nerves. In low spinal there is no fall of blood-pressure.

Total spinal anæsthesia was first done by Jonesco with a small dose of stovaine and strychnine injected between first and second dorsal space. Even head and neck operations were thus done. It was found risky as the breathing stopped in several cases and artificial respiration had to be persevered with for some time.

Unilateral analgesia is obtainable by injecting a hyperbaric solution and keeping the patient on the affected side for a few minutes. Single hernias, localised operations, and one-sided thoracic operations, etc., could be done by this method, but if at all spinal is used for appendicitis, this method, as it does not give relaxation in the whole of the abdomen, may cause rigidity of muscles and shock, if exploration and manipulations are done. The advantage is that only one side of the body is analgesic, and the other limb can be moved by the patient, but the disadvantage is that he may reflexly move the other limb and begin to worry, if he is nervous.

Segmental spinal anæsthesia is a limited form of analgesia from the nipple line or umbilicus, as may be required, to the knees. It is obtained by excluding the sacral nerves. A heavy solution is injected, the patient put on the back, the head end of the table is lowered to 5°, with a pillow under the shoulders and head, and the thighs are kept well flexed on abdomen for a few minutes to keep the lumbar spine quite straight, thereby preventing the sagging of solution in the sacral region. The advantage is that the sensation below the knees is present, and the patient can move his feet if inadvertently burnt by hot-water bottles. The disadvantage is that as the thighs are kept well flexed up for about five minutes, valuable time is lost in preparing the patient and getting him ready after the injection.

Unilateral plus segmental can be obtained if the patient is left on the affected side with thighs flexed, after a hyperbaric injection, for about five minutes.

Peridural block. Here fluid is injected in the peridural space which is limited above the fusion of dura mater with

the periosteum at the foramen magnum, and which is continuous below with the sacral canal and laterally through the foraminæ with the paravertebral tissues. The needle should be pushed as far as the dura, which is not punctured. Aspirate to make sure that no cerebro-spinal fluid is obtained, then slowly inject altogether 30 to 50 c.c. of a 1 per cent or 1.5 per cent novocaine solution. After injecting 10 c.c., test if there is any sign of paralysis or analgesia of the legs which would suggest that the solution has entered in the subarachnoid space. The injected fluid diffuses through the intervertebral foramine along the perineural sheaths, and thus blocks the nerve roots; it does not percolate into the subarachnoid space as was formerly believed. Peridural block may be used in severe upper abdominal operations, all obstetric operations except version, and as a therapeutic measure for intractable pain in the back. In the latter case oily solutions are useful, having a prolonged effect. The advantages are that uterine contractions are not interfered with, and there is less bleeding because the uterus maintains its tone. The patient, being conscious, can co-operate; there is a painless second stage of labour if the injection is given when the cervix is fairly well dilated, and as the anæsthesia remains for about two hours episotomies and lacerations can also be repaired without further anæsthesia. The baby is not asphyxiated. The drawbacks of spinal anæsthesia, viz., fall of blood-pressure, respiratory depression, vomiting and headache are lessened. The disadvantage is that it is sometimes uncertain and takes a long time in the onset of analgesia.

Balanced spinal anæsthesia. This means that the patient is well premedicated, then only a small dose of spinal is given, and at once followed up by a very light inhalation anæsthetic with a high percentage of oxygen. It may be used for obese patients, the debilitated, jaundice and all poor risk cases, nervous patients and children. Its advantages are, it is safe, there is no nausea and vomiting during operation, no psychic shock, complete relaxation without dangers and depression of a pure spinal anæsthesia, e.g. fall of blood-pressure, etc., good oxygenation, better con-

valescence and absence of pulmonary complications, e.g. atelectasis.

Spinal zone anæsthesia. Krishner's technique is to keep the patient in Trendelenburg position, and to let out about 25 c.c. or more of cerebro-spinal fluid, and inject an equal volume of air; this air-bubble collects in the highest part of the dural sac in the sacral curve. Then a definitely hypobaric solution made in oil is injected, which being not miscible with cerebro-spinal fluid, remains between the air-bubble and the cerebro-spinal fluid. As two things cannot occupy the same place at the same time, three zones of layers are formed. The apparatus required is a cannula with a lateral opening just before its point, and a double syringe, one of which is large for aspiration of cerebro-spinal fluid, and injection of air, and the smaller one is for injecting the oily anæsthetic solution. The advantage is that the solution is placed at will and maintained in a definite segment of the spinal cord, and can be regulated as required. The sacral nerves are unaffected, and so there is sensation below the knees and in the perineal region, and movement below the knees is possible. There is less fall of blood-pressure. The disadvantages are that there are several difficulties in properly administring and regulating the dose, and the large amount of cerebro-spinal fluid withdrawn.

Fractional or continuous spinal anæsthesia, is useful in prolonged and difficult cases, e.g., gastrectomy, resections of gut, adherent intra-abdominal tumours, prolonged orthopædic work, etc. After the needle is introduced it is connected with a syringe fitted with a rubber tubing and stopcock. The solution is injected in small doses at a time with or without barbotage, as may be necessary, the patient lying on his back. The head of the table is slightly lowered and a hyperbaric solution can be made to gravitate to the desired height. The head is flexed with pillows under it, to accentuate the thoracic curve, so that the solution may be trapped there and not reach any higher. The necessary equipment consists of a rubber mattress which is five inches thick with a small portion removed from it in the lumbar region, or folded sheets are kept under the costal margin and the

buttocks, to allow the needle to remain in position without contact with the surroundings. A flexible needle is required. The advantages are that the duration of operation does not matter, and that instead of injecting a large dose all at once, the initial dose is supplemented by small doses as needed; hence there is less toxicity and fall of blood-pressure is not sudden or great.

It may be here of interest to state that recently a young English I.M.S. officer in the army, was charged with manslaughter before a general court-martial, because an English officer died from spinal anæsthesia after three hours. It was alleged, *inter alia*, that death was due to not keeping the patient in the Trendelenburg position after he was put back in his room. After my evidence he was acquitted. I explained that after some minutes when the nuropexia, i.e. fixation or impregnation of the nerves with the solution takes place, there is no danger of the solution then diffusing up and poisoning the medullary centres as was formerly believed. The upward spread of the solution is checked by a brake action, due to the dentate ligament, posterior median septum, nerve-roots and the curvatures of the spine. The post-mortem findings were a hytrophied heart and some fatty infiltration of liver which were responsible for death in this particular case.

The Trendelenburg position is not essential post-operatively; it is mainly adopted in the hope of preventing headache.

ABSTRACTS

" Anæsthesia for Lobectomy." J. T. CHESTERMAN in *Archives of Surgery*, November 1943, p. 457.

The essentials of anæsthesia for lung resection are the prevention of anoxia, control of secretions and abolition of reflex disturbance. This is the author's recommendation, which he describes as simple and satisfactory: omnopon, gr. 1/3, and scopolamine, gr. 1/150 one hour before operation and the patient left in a darkened room with a decicaine gr. 1/2 lozenge in his mouth. Just before removal to the theatre an intratracheal catheter of about one-third the diameter of the trachea is passed with a laryngoscope and the preoperative medication is repeated with a dose of ephedrine. The patient is then placed in the lateral position on the table, which is tilted with a 10 degree slope, head downward, and as a spinal analgesic, hypertonic solution of nupercaine one in 1,500 is given. The intratracheal catheter is then connected with oxygen flowing at the rate of 2 litres a minute and attached to a valve so that a greater pressure than 1 cm. of mercury cannot occur. No local anæsthetic is injected into the region of the tubes for there is evidence that paralysis of the vagal branches to the lung may tend towards pulmonary oedema, especially if fluids are given intravenously.

" Complications of Trilene Anæsthesia." A. R. HUNTER in *Lancet*, March 4th, 1944, p. 308.

After some general observations and some details of appropriate instances the author summarises thus:

(1) Trilene is capable of producing serious disorders of cardiac function.

(2) It produces a well-marked increase in vagal tone, with a corresponding enhancement of the irritability of the vagal reflexes. The degree of vagotonia is proportional to the

depth of anæsthesia, and since the disturbances of cardiac rhythm seem to be caused by vagal irritability, deep anæsthesia affords no protection against them. The two fatal cases of cardiac failure reported under trilene anæsthesia appear to be due to vagal inhibition.

(3) It may produce convulsions during anæsthesia and may leave drowsiness or mental confusion for some hours afterwards.

(4) It may put the fifth and perhaps the second cranial nerves out of action for a considerable time.

"*Cranial Nerve Palsies with Herpes Following General Anæsthesia.*" J. H. HUMPHREY AND MARGARET MCCLELLAND in *British Medical Journal*, March 4th, 1944, p. 315.

Thirteen instances are cited of this unusual post-anæsthetic phenomenon—cranial nerve palsy. The nerves involved were mainly the fifth and seventh, but the third, fourth, sixth, tenth and twelfth were sometimes affected. There was labial herpes in nine of the patients. No anæsthetic drug was common to all, but all the anæsthetics were administered on a circle absorber machine.

Evidence is given for chemical reactions between soda-lime and trichlorethylene in the system, with the production of dichloracetylene. Preliminary experiments show that this substance is toxic to rabbits. Antibodies against herpes were shown in the sera of all the patients.

It is concluded by the authors that until further investigation has been made trichlorethylene (trilene) should not be used where there is any possibility of its coming into contact with soda-lime.

"*Hazards in the Use of Closed Circuit Technique for Trilene Anæsthesia.*" S. CARDEN in *British Medical Journal*, March 4th, 1944, p. 319.

Two accounts are given of patients who suffered from cranial nerve palsy. For the first operation no trilene was used, but the same apparatus had been employed with closed

circuit technique to give trilene to the patient immediately preceding her. The second patient had nitrous oxide, cyclopropane, oxygen and trilene by the closed circuit technique.

The amount of caustic soda available for chemical reaction with trilene is higher in some brands of soda-lime than in others. The reaction is favoured by heat and occurs readily at blood heat.

The palsies, caused presumably by dichloracetylene resulting from trilene decomposition, are disabling and may be permanent.

See also *British Medical Journal*, December 25th, 1943, p. 828. H. J. V. Morton.

"*Anæsthesia in Fractures of the Jaws.*" R. P. W. SHACKLETON in *Lancet*, March 25th, 1944, p. 396.

The outstanding problem is establishment and maintenance of the airway. Displacement of bony and soft tissues, blood and other debris in the pharynx, and associated head injury and shock make a good airway of prime importance. Until this is established the chance of improving the patient's general condition or of inducing general anæsthesia is impossible. The author writes on an experience of 156 patients with fractured jaws untreated before admission to his unit. In most cases operation was undertaken as soon as possible after admission. Omnopon gr. 1/3 and scopolamine gr. 1/150 were usually given an hour before operation. The patient was then placed on the operating table before induction which was most often with intravenous pentothal. The dose needed was small. As soon as consciousness was lost a No. 6 or 7 Magill tube was passed through the clearer nostril to a point beyond the base of the tongue and manipulated until free respiration was evident. Then a mask was applied and anæsthesia continued with a gaseous anæsthetic. Cyclopropane and oxygen was the preference particularly for the bad risk patients. When this was unavailable gas-oxygen-ether, or induction by cyclopropane followed by ether maintenance were employed. Anæsthesia was taken to Guedel's third stage (second plane) and endotracheal intubation then performed. The largest possible Magill tube

was used. Where blood or debris was known to be present in the pharynx suction was carried out before intubation.

Tracheal suction was done whenever inspection showed possibility of inspired blood being present. Often stale dark blood was aspirated from the trachea. After intubation the pharynx was packed with sterile gauze bandage impregnated with soft paraffin.

The article gives tables of post-operative morbidity. There were two deaths in the series—from secondary hæmorrhage and subarachnoid hæmorrhage.

ANÆSTHETICS ON THE SCREEN

The following quotation from the *Lancet*, June 24th, will interest our readers:—

There is no doubt that the cinematograph might with advantage be much more widely employed than it is in the service of medical education. Perhaps it is held back chiefly by technical and financial difficulties which obstruct the authorities of the medical schools. If that is so, we must hope that they will be speedily overcome in the after-the-war years. In the meantime, it is good to see a great commercial undertaking stepping in to help. With the collaboration of the department of anæsthetics of Westminster Hospital the Imperial Chemical Industries have produced a series of films illustrating the use of anæsthetics. The first three, shown on June 12th, took about an hour and a half. The design of the exhibition was excellent and its production no less so. The film, on open drop ether, demonstrated the method in practical detail. All necessary apparatus was assembled and explained, including airways, gags and masks, and drops for the patient's eyes at the close of operation. The lecturer described clearly and simply everything that was done, his remarks synchronising well with the action. The two other films, showing endotracheal and intravenous methods, were just as good and comprehensive. The U.S. Medical Corps in Britain has already adopted these films for instructional purposes. They may be obtained by hospitals, medical schools and medical branches of H.M. Services, and it will be a pity if they are not widely seen by medical audiences. They can be had on loan from the Central Film Library, Imperial Institute, London, S.W.9.

REVIEW

"The Blood-pressure and its Disorders." JOHN PLESCH, M.D. pp. viii + 150. 56 illustrations. Price 15/- net. Ballière, Tindall and Cox, London.

Although this little book contains no specific reference to anæsthetics in relation to blood-pressure, yet anæsthetists are so constantly concerned with blood-pressure variations that they may be interested to read this very detailed study. The author has original ideas, particularly concerning angina pectoris, of which he says "the prevalence of coronary symptoms has given rise to the opinion that angina pectoris is localised in the coronary circulation. We will now discard this hypothesis as it is less than helpful to further investigation. There is no known fact which would justify the assumption that angina pectoris is specifically a heart disease. On the contrary, all the evidence of pathological anatomy points towards it being a disorder of the whole circulation."

He describes two forms of arteriosclerosis with the second of which angina pectoris is concerned. "This is a disease in itself, a constitutional, systematic allergic primary affection of the smooth muscles, the sympathetic nerves and the connective tissue."

The arterial blood-pressure is discussed at great length and illustrations given of apparatus which the author uses and considers more accurate than most commonly employed methods of gauging blood-pressure. Whether one accepts all the author's conclusions or not his book is worthy of study for it is the outcome evidently of much investigation and of serious critical thought.